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The Electrical Properties of Thin Films of Nickel at Very Low Temperatures

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Thin nickel films were obtained by thermal evaporation in glass tanks under the pressure of 10^{-7} mm. During the process of deposition the instrument was submerged into a helium bath allowing to obtain ferromagnetic films of very high purity.

Electrical properties of the films were studied including the electrical resistance temperature dependence from 2 to 300°K and Hall electromotive force.

At low temperatures residual resistivity was observed close to that of nickel bulk specimens. The results were obtained on films ranging from 30Å and thicker. Hall electromotive force of the said films was of the order of Hall electromotive force in bulk specimens.

A considerable number of papers have been devoted to the study of ferromagnetic films. However, the peculiarities of the magnetic properties of the films obtained in a vacuum of the order of $10^{-5}\sim10^{-6}$ mm discovered by some of the authors[1,2], as has been shown by more recent investigations by Neugebauer[3] are to a considerable degree associated with the influence of residual gas impurities during evaporation and with the oxidation of the film when exposed to the air. In particular, the paper[3] has shown that the saturation magnetization of thin films of nickel evaporated in a vacuum of 10^{-9} mm up to a thickness of the order of 30 Å does not depend on the thickness.

The present research was carried out to determine to what measure the electrical and galvanomagnetic properties of the films with a thickness up to 30 Å evaporated in a vacuum of the order of $10^{-7}\sim10^{-9}$ mm differ from the corresponding properties of bulk specimens.

The films were obtained by thermal evaporation of nickel. Fig. 1 shows the general view of the evaporation apparatus. Tungsten wire was used for the evaporator with nickel wires wound on its middle part. Following the treatment of the evaporator (purification degasation, vacuum training at 10^{-7} mm) a substrate was soldered into the ampule and the complete apparatus was subjected to redegasation in the same vacuum. Tumblers which were optically polished to 0.1 of interference band were taken for the substrate. Four platinum leads were soldered into the butt end of the tumbler. Current and Hall contacts were deposited on the substrate by cathode evaporation. For the time of film depositing the apparatus was placed in a helium bath. Thus, the residual gases, besides helium were frozen. The pressure in the apparatus prior to evaporation was appreciated by the volume of helium in the atmosphere and it comprised a value of the order of 10^{-13} mm mercury column. The volume of the deposited metal was checked by measuring the electrical resistance in the process of evaporation.

The temperature dependence of the electrical resistance was studied on films ranging from 1,300 Å to 30 Å, at the temperatures of 2°K 200°K. The measurements of the temperature in the temperature range 4.2°K-40°K were conducted by a constant resistance thermometer and by a copper-constantan thermocouple above 40°K. The film thickness was determined by the interference method by using a universal monochromator.*

Fig. 2 shows the curves describing the change of the electrical resistance in the studied films when the freshly condensated films were heated from 4.2°K to 300°K and during cooling to initial temperature (4.2°K) after holding at 300°K. The repeated heating does not evoke further alteration in the 3.4 curves. The calculation has shown that the film resistivity for all the said thickness is close to that of bulk nickel. The violation of the vacuum (the exposure of the film to the air after three months of preservation in an ampule) entailed immediate and radical increase in electrical resistance: The resistance of thick films increased 1.5-2 fold, that of the thin films—several scores fold.

Fig. 3 shows the curves describing the R_T/R_τ dependence on the temperature of annealed films for different thicknesses. Here

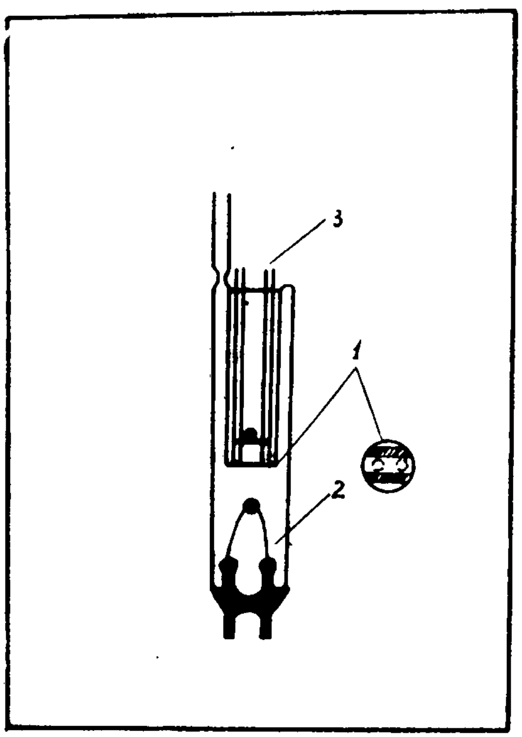

Fig. 1. Apparatus for film depositing.
1. Substrate with the deposited platinum contacts.
2. Evaporator.
3. Platinum electrodes.

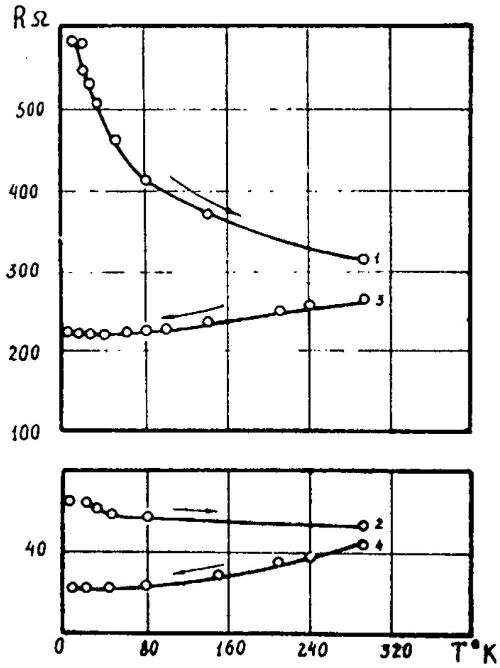

Fig. 2. 1. The change in the electrical resistance of fresh deposited film 50 Å thick heated from 4.2°K to room temperature.
2. The same for film 135 Å thick.
3. The change in electrical resistance of a film 50 Å thick cooled from room temperature to 4.2°K after keeping in room temperature for 18 hours.
4. The same for a film 135 Å thick.

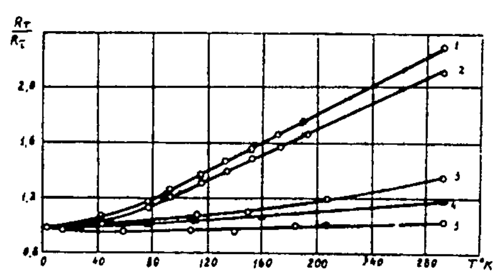

Fig. 3. The R_T/R_τ dependence on temperature for films of varying thickness.
1—d=1,300 Å
2—d=935 Å
3—d=135 Å
4—d=75 Å

* Film thickness was determined by Y. Durasova

R_T is the film resistance at the temperature T, R_τ the resistance at helium temperature.

The thinner the film the smaller the relative change of resistance with temperature increase. For the films of 1,300Å thickness $R_\tau/R_0=0.4$, where R_0 the room temperature resistance. For films which are 30Å thick $R_\tau/R_0=0.95$. Besides, the curves indicate that the residual resistance region border for thin films is shifted to higher temperatures.

Fig. 4 shows the curves describing the dependence of resistivity from film thickness for temperatures of 300°K and 4.2°K.

It is seen from the drawing that at 300°K the resistivity of films with thicknesses ranging from 1,300Å to 300-400Å does not depend on thickness and slightly increases with the drop in the thickness of thin films where thickness ranges from 300Å to 30Å. At 4.2°K the increase in resistivity with a drop in thickness is observed already for films with thickness below 900Å. Resistivity drops 2-2.5 fold in the transition from room temperature to helium temperature in thick films ($d>1{,}000$Å) and only by 4-5 per cent in thin films ($d<100$Å).

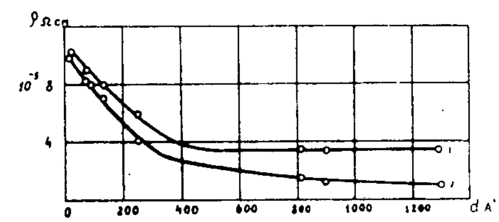

Fig. 4. The dependence of resistivity from film thickness.
1—300°K
2—4·2°K

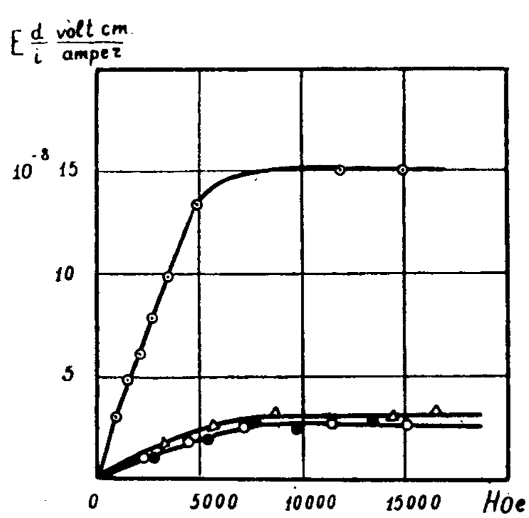

Fig. 5. The dependence of Hall field for films of different thickness on the external magnetic field.
◉◉◉ —50 Å
△△△ —835 Å

We have studied also the galvanomagnetic effects and Hall effect in particular.

Fig. 5 shows the curves of Hall field dependence upon the H magnetic field, directed perpendicular to the film plane. The measurement of Hall field was carried out at room temperature. For thickness of 1,300-835Å Hall field is approximately the same for bulk specimens. During the transition to a film with a thickness of 50Å Hall field increases which apparently associated with the increase in resistivity.

Conclusions

1. Resistivity and Hall field of films obtained when the apparatus with the substrate and the evaporator are in a helium bath during the depositing are close to the resistivity and Hall field of bulk metal specimens.

2. The temperature dependence of thin film resistance is characterized by a considerable expansion of the residual resistance region. The increase in resistance with temperature for the film of 30-50 Å thickness starts with nitrogen temperatures.

3. An increase in resistivity with a drop in thickness is observed in films below 300-400Å. At room temperature the resistivity of a 30Å film is 2.5 fold that of a film 400Å thick.

4. Preliminary estimates show that the peculiarities of resistivity and its temperature dependence in thin films below 300-400Å is apparently due to the fact that the free path of electrons in these films become comparable to the thickness of the film.

In conclusion the authors express their gratitude to A. I. Shalnikov for his valuable advice and great assistance in carrying out the said work.

References

1 A. Colombani, G. Goureaux, P. Huet: Colloque International de Magnetisme, Juillet (1958) 239; la Recherche Scientifique, Paris (1959).

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2 **N. I. Ginzburg**, A. M. Polyakov, Jurnal technicheskoi Physiki **28** (1958) 1029.
3 C. A. **Neugebauer**: Structure and Properties of thin Films by C. A. Neugebauer, J. B. Newkirk, B. A. Vermilyea: John Wiley, New York (1959) 358.

DISCUSSION

P. B. Hirsch: 1) What is your explanation for the strong decrease in resistance after the first heating? Such a decrease can not be due to mechanical stresses. 2) Have you found some relation between the measured Hall effect in the very thin films and the corresponding magneto-resistance effect?

E. I. Kondorsky: 1) The irreversible decrease in resistance of this film was found only in process of first heating and, as we propose, can be due to decreasing of initial mechanical stresses which may be very large in our case after deposition. 2) The simple relation was not found between the Hall field and magnetoresistance effect in very thin films.